Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 21 (2014) 449 – 454

www.elsevier.com/locate/procedia

24th CIRP Design Conference

DEVELOPMENT OF A MODEL FOR EVALUATING THE NPD PROCESS IN SMEs: A LATIN AMERICAN EXPERIENCE

María Cristina Hernandez[a]*, Marcela Velásquez Montoya[a], Jose F. Martínez[a]

[a]*Design Engineering Research Group, Universidad EAFIT, Medellín, Colombia*

* Corresponding author. Tel.: +574 261 9500 ext 9752; fax: +574 2664284. *E-mail address:* mhernand@eafit.edu.co

Abstract

This article presents the findings resulting from a research project carried out in Medellin, Colombia, that was aimed at developing a model of diagnosis for the NPD process in manufacturing SMEs, adapted to the Latin American context. Four aspects were considered to develop the model: (i) Rational logic for problem solving based on the paradigm that a problem can be solved through systematic application of general principles and standardized knowledge, (ii) The Grounded Theory research approach, (iii) Integration of learning processes based on reflective and, (iv) Kolb's learning cycle as basic premises for the generation of a prescriptive model considering that the diagnosis process involves a learning process. Results obtained from the four companies selected for the study helped to validate an initial version. The model has proven to have great potential to improve the NPD process, as well as an opportunity to develop future comparative studies. Findings in the discussion and further reflection generated by the application of the four tools that encompasses the model within the companies, proved to be appropriated as a reflective practice and also a continuing learning process for SMEs.

Selection and peer-review under responsibility of the International Scientific Committee of "24th CIRP Design Conference" in the person of the Conference Chairs Giovanni Moroni and Tullio Tolio

Keyword: Regional Product Development; New Product Development Process; Business Diagnostic Tools; Design Management.

1. Introduction

This article reports on research that aimed at developing a diagnosis model for evaluating the New Product Development (NPD) process in small and medium sized enterprises (SMEs). The project was carried out in Medellin-Colombia, and one of its main goals was to study and adapt some of the models found in literature to the Latin American context.

SMEs in Colombia play a significant role, as they represent 96% of the total market, generate 76% of employment and are responsible for 40% of total wages of the country. However, little attention is paid to product design and NPD processes and most of the research done by some government agencies, trade unions and universities are focused on financial, productive and logistic issues. Research and consultancy projects undertaken by the Design Engineering Research Group (GRID) of Universidad EAFIT [1,2,3,4] found that (i) specific information about NPD in SMEs such as strategies, portfolio management, processes and metrics is absent from the documentation in almost all of the companies studied, (ii) the consultancy projects related to NPD were outsourced and most of them didn't generate a knowledge base for the SMEs, and (iii) some existing audit tools employed for assessing the NPD process [5,6,7] lacked coherence with SMEs business reality [1,2,3,4] due to language issues –DTI self-assessment tool [5]- and the tendency to overestimate or underestimate SMEs level.

The importance of evaluating NPD processes both for practitioners, mainly managers and consultant, and academics have been addressed in several studies found in the NPD literature [8,9,10,11,12,13,14,15,16,17,18,19] and some of the audit tools and constructs proposed are available [5,6,7,8,14,15,19]. However, the use of such tools is restricted for a Latin American context, as our experience in Colombia has shown, due to language issues (technical and idiomatic) and the adaptation of best practices found in NPD literature to the SMEs of under-developed and developing countries [1,2,3,4].

Thus, one of the most important outputs of this research was the development of a novel NPD audit model and its

Selection and peer-review under responsibility of the International Scientific Committee of "24th CIRP Design Conference" in the person of the Conference Chairs Giovanni Moroni and Tullio Tolio
doi:10.1016/j.procir.2014.03.123

associated tools, developed iteratively through application in action research mode after Moultrie et al. [19] and considering Latin American context issues. This article reports specifically on the development of this model, which targets the "Strategic Situation of the Company" and "Product Development" stages of the NPD process following Buijs [20].

Accordingly, the article is structured in 3 sections. The first section presents the methodology of the research project and its main characteristics. The second section describes the main aspects considered for the development of the NPD process evaluation model and the model itself. Finally, in the third section, the main findings and conclusions are summarized.

2. Methodology of the research project

Following Moultrie et al. [19] a Procedural Action Research approach was used for the development of the NPD process evaluation model. Figure 1 shows the four phases that comprised the methodology. Each phase is described in more detail below.

Fig. 1. Research Methodology

2.1 Phase 1. Exploratory Study.

In order to develop a model for evaluating the NPD process in SMEs during the first phase of the research, several activities were conducted: (i) a literature review, (ii) an analysis of existing NPD models, (iii) identification and selection of best practices in NPD, (iv) an inventory of diagnosis tools for NPD, and (v) the application of three audit tools [5,6,7] in six SMEs as summarized in Table 1.

Table 1. Companies and Tools applied

Companies	Personnel Position	Tool applied	G	A
Senco	R&D Engineer	Corporate Audit tool Product and Design		X
	General Manager	Self-diagnostic tool	X	
Plasdecol	Product Development Director	Self-diagnostic tool	X	
Analytica	Design and Development Director	Self-diagnostic tool		X
Industrias Médicas Sampedro	General Manager	Managing for success-DTI	X	
Celsa	Mechanical Department Director	Managing for success-DTI	X	
Plesco	General Manager	Managing for success-DTI		X

G: Guided assessment
A: Self-assessment

The completion of this activity brought different conclusions, a very positive outcome for the research group to the extent that they helped to identify and verify the shortcomings and weaknesses of each tool applied in order to consider the conclusions for the development of the new tools:

- Must have terms that can be understood in the context of Latin American SME's.
- Should not exceed more than 30-45 minutes and be answered by one person.
- It is pertinent to consider 3 to 5 levels when using Likert scale types.
- Should be applied in companies where there is a design management activity.
- Would help to identify strengths and weaknesses related to the best practices.

2.2. Phase 2. Model Construction.

Informed by findings from the exploratory study, the research group took the following issues for the construction of the model into account: The definition of the general model and the development of its tools and instruments. Thus, four tools were created: (i) an "alpha version" of the initial diagnostic tool, (ii) a guide for the application of such tool, (iii) a game for in-depth evaluation called "Diagnosis" and (iv) a SWOT workshop. Then, initial feedback was sought using the Delphi method. The people involved in the process were selected taking the following into account: they are connected to processes of consulting, with experience in developing research projects and, professional experience and links with the academia. To check the consistency of the questions, the experts were asked about the following aspects: (1) the relevance, (2) the total time invested and, (3) the easiness to answer each question. The experts suggested a number of changes in relation to delivering visible results together with the strengths of the analysed company, and some input on how some questions could be improved. Experts highlighted the quality of the material in general, the quality of questions and the structure of the developed tools.

2.3. Phase 3. Model Development.

According to the results of phase 2, some modifications to the tools were made. Subsequently, the alpha version of the initial diagnostic tool was applied in three companies in action research mode as summarized in Table 2.

Table 2. Companies, Contacts and Positions

Company	Contacted persons	Position
Scanform S.A	4	Operations manager Design Department-person 1 Design Department-person 2 Sales Manager
Rotoplast S.A	3	General Manager Design Department Projects Area
C.I. Laboratorio de Ideas	2	General manager Design Department – person 1

During the application and considering the comments of respondents, it was necessary to clarify some questions for better understanding. The average length was also checked, which is estimated to be between 1½ to 2 hours, as well as the need to validate the participation of 2 consultants so that one

leads the session and the other consolidates the information in the tables developed by the research group for this purpose. The game Diagnosis was also applied in the Market Development area of Scanform S.A in order to corroborate the consistency and security of the answers given by participants.

2.4. Phase 4. Model Validation.

From the results of the previous phase, a final version of the guide and the initial diagnostic tool (beta version) are generated in order to apply the complete model in a local company. The results obtained after applying the four tools of the model were the following:

Initial diagnostic tool: The main objective was to identify the most significant weaknesses and the current status of the organization and to develop a plan to address these shortcomings. The dynamic was first a training session in handling the tools. As part of the training, the information of the guide was analysed to explain the tools that compose the initial diagnosis. The initial diagnostic tool was applied to 4 directors and heads of the most important areas within the company. Each was handed a copy of the tool to mark the answers to analyse and get results. At the same time, comments were recorded and transcribed later on. The application of this tool took 2 hours for each person. The results showed an early diagnosis and consolidating information table.

SWOT workshop: The main objective was to identify the opportunities, strengths and weaknesses identified by each area director in the company and in his own department, regarding the development of new goals and strategies. The dynamic was carried out with the directors of the most important areas: the administrative area director, the director of design and the production manager. Each was given some cards, a different colour for each director, with topics to discuss. Each participant individually relates the theme of each card with the company's current situation and writes their positive and negative findings on the card. Some of the topics discussed were: distribution channels, product positioning, technology skills, management of the design process, cost structure and product differentiation from the competition, among others. Results included 3 SWOT matrices that were developed: SWOT matrix of the company, the SWOT matrix of the team and SWOT matrix of the current product portfolio.

Game Diagnosis: According to the instructions, not all the cards need to be used because some issues might not apply. In the case of the selected company, the results of the initial diagnostic tool and SWOT noted the need to use the 18 cards of the game to evaluate different phases of the NPD. The main objective was to generate discussion on the 6 themes of the game. The dynamic of the activity was carried out with the same people who took part for the initial diagnostic tool. One by one the results were consolidated in the table, and the conversations were recorded. This activity led several issues to light that were not taken into account in previous activities. One of the most important is that management is aware of the company's strategic situation and the lack of technology to innovate in products. Parallel to these results, participants offered some feedback on the game dynamics to the research group.

From the SME point of view, the results of the application of the NPD evaluation model led to the following actions:

- A new model of the NPD process in line with the company structure.
- A new product line was developed to validate the model with all its tools.
- A new line of products was launched reporting excellent results for the company.

3. The NPD evaluation model and its main characteristics

The NPD evaluation model (Figure 2) consists of four main stages: planning, initial diagnosis, in-depth diagnosis and conclusion. It can be defined as a parallel process of learning which feeds each stage.

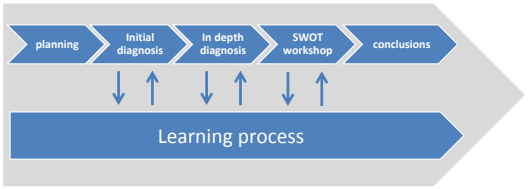

Figure 2. General outline of the methodology

The learning process is made explicit in the graph of the methodology, since, as exposed above, one of the added values of the proposal is that the organization, under the guidance of the consultant, is no longer a passive entity that is limited to expected results, but becomes an active participant of the process that builds its own diagnosis. Besides the organization, the consultant is also immersed in the learning process. As the consultant moves into the diagnosis process and audit, he begins to understand the company and to identify factors that explain the behaviour and performance in terms of the design and development of new products. This learning is the guarantee that the diagnosis of the organization is adjusted to reality and allows, later in the stage of conclusions, to make relevant recommendations and suggestions aimed at improving the NPD practices identified for the company.

Some of the main considerations taken in account for the NPD evaluation model development were:

Using the paradigm of rational logic to solve problems: Rational logic for problem solving [21] is based on the paradigm of technological rationality, derived in turn from the positivist epistemology. In this paradigm, a problem can be solved through systematic application of general principles and standardized knowledge (proposed and accepted by a particular academic community [22]. This was evident in the design of the research and implied that, after the study and analysis of the NPD Models, the best practices associated, and similar tools, a prescriptive model of diagnosis was generated, characterized by the consideration of analysis, synthesis and evaluation activities.

Consideration of the research method "Grounded Theory" to define the overall structure of the NPD evaluation model: From the perspective of the consultant, the diagnostic process in any organization has certain similarities with the processes and methods of investigation suggested by

the social sciences. In particular, some similarities were found with the method "grounded theory" (GT) proposed by Glaser and Strauss [23]. The GT approach is inductive in nature and aims to generate, systematically, concepts, categories and theories from the data collection. The process followed in applying the GT consists of five steps as follows: Preparation, Collection of data, Comparative analysis, "Memoing "and Generation of theory.

Integration of learning processes in the methodology based on reflective practice and Kolb's learning cycle: One of the basic premises for the generation of a prescriptive model is the fact that the diagnostic process in a company involves the input of a learning process for the company. The research group (based on the notion that companies that employ a diagnostic process do it for their own interest), concluded that one of the added values of the methodology lies in the possibility of including the tools that privilege the participation of the companies and guide them to build up their own diagnosis. Therefore, the consultant is seen as a person who questions and guides the assessment but does not judge. Schön [22] and Kolb [24] models were revised to identify the best practices, and some relationships were generated to include them within the prescriptive model of the methodology.

The heuristic nature of the proposed model: Despite being framed in the paradigm of technological rationality and considering that the prescriptive model of the methodology was validated empirically and optimized according to the results of this validation, the constitution did not follow a pure deductive logic. Instead, it was characterized by considering aspects such as the researchers' experience in consulting activities, the views and recommendations of expert's organizational consultants, and the feedback of the companies throughout the diagnosis process. The fact that much of the measurement scales were generated from the best practices reported in the literature of the NPD is another example of the heuristic nature of the methodology. In fact, instruments, tools and procedures should be reviewed regularly according to the evolution of academic research on a regular basis with the development of academic and professional research on NPD processes.

The following are the 4 tools included in the NPD evaluation model

3.1. Guide for the interviewer.

The guide is the instrument that accompanies the initial diagnostic tool, which allows a scan of the organization. It was developed in order to facilitate the work of the interviewer who will use the four tools of the methodology for diagnosis. The guide consists of: how to make the approach to the business, a description of the initial diagnostic tool with directions on how to proceed in each of the 12 aspects that encompasses the tool. The guide helps the interviewer, in a didactic way, to develop each of the questions. It is made so that the interviewer understands what the intent of each question is and what to get from them.

3.2. Initial diagnostic tool.

For the construction of the initial diagnostic tool (alpha version) the following aspects were considered:

- From the literature review: management tools, target, type of measurement, and time spent.
- From the NPD models, two phases of the model "Circular Chaos"
- From the best practices, common issues and performance variables identified.
- From the inventory of tools: general conclusions and type of questions used.

The development of the tool is focused on linking the two phases of "Circular Chaos". Based on the topics selected and comparing with existing tools, the best way to ask the questions to respondents was chosen. The alpha version of the initial diagnostic tool has the following type of questions: Likert scale, Yes/No Questions, Radar, Open questions, Multiple choice questions and Questions of relationship.

During the development of the Alpha version of the initial diagnostic tool, considerations were given to graphic design in order to facilitate both the consultant and the respondent to advance in each of the subjects. Finally, the first version of the tool was applied in 3 selected companies.

3.3 Game "Diagnosis".

Considering the fact that the initial diagnostic tool provides an overview of the state of the company in selected areas of the NPD, but does not look into specific aspects of them, nor does it allow the assessment of the reasons behind each of the answers, the research group developed an instrument for in-depth diagnosis in selected areas.

To address this problem, named by the group *"moving from the intangible to the tangible"*, it was decided upon to identify companies doing design consulting for product development in the international context and to review tools used by these companies when doing consulting work. On the other hand, identifying which of these tools could be applied to finding problems in-depth and, based on the tools analysed, select one of them and develop a new one for inclusion as the four tool of the methodology. From 20 international companies, 6 were selected: Frog Design-Germany, Landor-United States, Ziba-United States, Doblin – United States, Sunidee – The Netherlands and IDEO - United States. 18 tools were analysed and classified as follows: How to use the tool and what is wanted to be achieved. For this aspect, the triangle Say, Do and Make [25] was used. A card was designed to classify each tool according to the phase and sub-phase to which it belongs: strategic situation of the company and product development.

Based on those concepts and tools used by international companies, the group observes the possibility of developing a game that would make in-depth analysis of those areas identified as critical in the initial diagnostic tool. It was decided to analyse the board game "Personality" which has elements similar to the "Brain tornado" (from Sunidee) and "IDEO method cards" (from IDEO), which facilitate the active participation of a group of people. With this background, the group developed the game Diagnosis to perform in-depth analysis of the problems identified after applying the initial diagnostic tool. The game focuses exclusively on Part 2 of the tool "Product Development".

The game consists of 18 cards, through which it is possible to learn more about the problems associated with issues of:

planning, market development, tools for creativity, research and development, patents and development of manufacturing. The dynamic proposed is participatory (maximum 6 people), so that in the discussions of the participants the consultant could accurately identify specific details of the problems and check the consistency between the information found after the application of the initial diagnostic tool and the information arising from the discussions.

3.4 SWOT workshop.

For the workshop it was considered appropriate to include a series of questions related to the knowledge that the company had on: its opportunities, threats, strengths and weaknesses. To formulate those questions, these aspects were considered relevant for the companies: external analysis, internal analysis to identify strategic strengths and competencies. Considering the scope of the initial diagnostic tool and the issues contained, it was determined that the SWOT matrix must consider three basic aspects: Persons, Processes (organizational and technological) and Products. With regard to the above, a number of issues and guidelines were generated for the construction of the SWOT matrix making the distinction whether they belonged to: materials and processes (MP), people (P), product (Pd), financial (AF) or general (G). Each of these topics should consider their strengths and / or negative effect, and also if it is an opportunity, threat, strength or weakness.

With regard to the SWOT matrix, the methodology proposed to hold a workshop after the execution of the game. The workshop should involve a multidisciplinary group with people from both the management and the operating level. It can last between 1 to 2 hours, whereas there is already sufficient information resulting from the initial diagnostic tool and the Diagnosis game. The SWOT workshop has visibility in Part 1 of the initial diagnostic tool and is a combination of internal strengths and external opportunities that are presented to the company to set parameters to help processes in further consulting.

4. Conclusions

A significant result of the literature review is the consolidation of a robust state of the art with very important information for the research group. The analysis of the information was structured in a table based on these variables: No. of document, subject, author, title, reference (cited in), source (journal, book, etc.), keywords, variables measured, type of measurement, time spent, administration, target group, sample size, tool or instrument used, questions or hypothesis involved. The tables generated were used to: compare information found, to identify common issues and draw conclusions to generate key criteria for the construction of the methodology of diagnosis for new product development processes.

The review of the best practices identified 26 variables and how they are measured. Some variables are: Financial performance, Customer satisfaction, Market attractiveness, Development process performance, Strategy and leadership, Technological acquisition, Knowledge and Project Management, Access to New Markets, Business performance, Culture and climate for new ideas, Team communication and collaboration, Commitment at Senior management's level, Design effectiveness and design efficiency, Concept generation and Idea evaluation, Product development cost, Percentage sales from new products vs. total sales, Product development and strategic alignment, etc. The group is aware that, given the changes that occur in the process of design and product development, it is necessary to make a permanent monitoring of the best practices to adapt the tool to these changes, so that current analyses can be made regarding the best practices.

In relation to the application of the initial diagnostic tool (Parts I and II), it allowed to identify the weaknesses associated with each of the twelve parts of the instrument. Similarly, once these weaknesses were identified, the game Diagnosis allowed to discuss in-depth the issues related to each of those identified. During the discussion, the participants suggested corrections in order to improve the tool. Although this was not planned as part of the methodology, it becomes an added value of interest to companies that are offered consulting services for the diagnosis, as clearly indicated the way forward and in many cases, the way to make corrections.

In connection with the development of a participatory methodology, the most important issue was to prevent intervention by a consultant who just goes and gets information and then comes back with a sound-solution. As was observed during application of the instruments, it is possible to say that the process is a one of learning for the company to the extent that, together with the consultant, everybody involved is part of this process which is able to diagnose their own business.

Finally, the group has a methodology of diagnosis which consists of one guide for the consultants and three application tools, making it possible to provide consulting and advisory services for SMEs in the manufacturing sector. The methodology is replicable, making future comparative studies possible for companies and sectors that design and develop new products, in which the methodology has been applied so that it can be improved, and also to generate case studies and examples that can be socialized in training programs in the future, allowing expanded knowledge issues associated with this research.

5. References

[1] Martínez, J. F. (2006). Implementación de un nuevo proceso de desarrollo de productos para la empresa COLPLAST LTDA. Tesis de maestría, Universidad EAFIT, Medellín.

[2] Martínez, J., & Hernández, M. C. (2006). Análisis de la actividad de Diseño como factor de Innovación en las empresas de manufactura del sector plástico en Antioquia. Informe de Investigación, Universidad EAFIT, Medellín.

[3] Hernández, M. C., Martínez, J. F., & Velásquez, M. (2007). Construcción de una metodología de diagnóstico y auditoría en procesos de desarrollo de nuevos productos para PYME's del sector manufactura en Colombia. Informe de Investigación, Universidad EAFIT, Medellín.

[4] Hernández, M. C., Velásquez, M., & Martínez, J. F. (2010). Revisión y prueba de la metodología de diagnóstico en procesos de desarrollo de nuevos productos para PYMES de manufactura. Informe de Investigación, Universidad EAFIT, Medellín.

[5] Goff, D. (1998). Managing for success: a self-assessment workbook. London, United Kingdom: DTI - Department of Trade and Industry.

[6] Lecuona, M. (2006). An auditor's questionnaire and conclusions on design management. Foresting Strategic Design Cultures. II, 1-12. Design Management Institute Press.

[7] Lecuona, M. (2006). Pla de Consolidació i Competitivitat de la PIME (2000-2006) Disseny. La gestió de disseny per empreses que obren nous mercats. Universidad Politécnica de Valencia, Valencia.
[8] Chiesa, V., Coughlan, P., & Voss, C. A. (1996). Development of a technical innovation audit. *J PROD INNOVAT MANAG*, Volume 13, Issue 2, 105-136.
[9] Griffin, A., & Page, A. L. (1996). PDMA Success Measurement Project: Recommended measures for product development success and failure. *J PROD INNOVAT MANAG*, Volume 13, Issue 6, 478-496.
[10] Kerssens-van Drongelen, I. C., & Weerd-Nederhof, P. C. (1999). The use of performance measurement tools for balancing short and long-term NPD performances. *Int. J. Innov. Mgt.*, 03(4), 397-426.
[11] Cooper, R., & Press, M. (1999). The Design Agenda: A guide to successful design management. Londres: John Wiley & Sons.
[12] Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. (2002). Optimizing the stage-gate process: What best-practice companies do I. *RES TECHNOL MANAGE* 45(5), 21-27.
[13] Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. (2002). Optimizing the stage-gate process: What best-practice companies do II. *RES TECHNOL MANAGE*, 45(6), 43-49.
[14] Inns, T. (2002). Design Tools. In M. Bruce, & J. Bessant, Design in Business: strategic innovation through Design (pp. 222-276). London: Financial Times/Prentice Hall.
[15] Oliver, N. (2002). Performance measurement and benchmarking. In M. Bruce, & J. Bessant, Design in Business: Strategic innovation through Design (pp. 213-236). London: Financial Times/Prentice Hall.
[16] Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. (2004). Benchmarking best NPD practices 1. *RES TECHNOL MANAGE*, 47(1), 31-43.
[17] Cooper, R., Edgett, S. J., & Kleinschmidt, E. (2004). Benchmarking best NPD practices 2. *RES TECHNOL MANAGE*, 47(3), 50-59.
[18] Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. (2004). Benchmarking best NPD practices 3. *RES TECHNOL MANAGE*, 47(6), 43-55.
[19] Moultrie, J., Clarkson, P. J., & Probert, D. (2006). A tool to evaluate design performance in SMEs. *International Journal of Productivity and Performance Management*, 55(3/4), 184-216.
[20] Buijs, J. (2003). Modelling Product Innovation Processes: from linear logic to circular chaos. *Creativity and Innovation Management*, 12(2), 76-93.
[21] Simon, H. (1995). Problem forming, Problem finding, and Problem Solving in Design. In A. Collen, & W. W. Gasparski, Design and Systems: General Applications of Methodology, Vol. 3, pp. 245-257. New Brunswick, NJ: Transaction Publishers.
[22] Schön, D. (1983). The Reflective Practitioner. New York: Basic Books.
[23] Glaser, B. G., & Strauss, A. L. (1999). Discovery of Grounded Theory: Strategies for Qualitative Research. New Jersey: Aldine Transaction.
[24] Kolb, D. (1984). Experiential Learning: experience as the source of learning and development. Englewood Cliffs: Prentice Hall.
[25] Sleeswijk Visser, F., Stappers, P. V., & Van Der Lugt, R. (2005). Context mapping: Experiences from practice. *CoDesign: International Journal of Co-Creation in Design and the Arts*, 1(2).